PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Improvements in or relating to Light Modulation Devices

We THE PLESSEY COMPANY LIMITED, a British Company of 56 Vicarage Lane, Ilford, Essex, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to light modulation devices.

A change in the refractive index of certain ferroelectric cubic crystals can be observed when the crystal is an electric field. The relative change however is not large even in the presence of a field of high intensity. For example with an electric field of intensity 10 Kv/cm the change of refractive index upon removing the field may be only about 0.1% or less. A change of this order would not readily provide suitable direct modulation of light over a useful optical range. It is proposed that a medium of variable refractive index be used as a layer of an optical interference filter in which the refractive index may be varied by electrical means. A small change of refractive index can then be made to have a critical effect on the intensity of light transmitted by the filter.

According to one feature of the invention a light modulation device comprises a stack of thin layers of transparent material, the layers having alternating high and low refractive indices and including one layer the refractive index of which may be varied by application of an electrical potential to the device.

A filter of the Fabry Perot type which comprises a stack of thin layers having alternating high and low refractive indices can be made with very high peak transmission and yet a very narrow band-pass range, for example as little as 15 Ångstrom units. A conventional Fabry Perot interference filter has a central layer of high refractive index ond thickness $\frac{\lambda}{2}$, on either side of which are arranged alternate layers of low and high refractive index of thickness $\frac{\lambda}{4}$. In this context λ is the peak wavelength of light transmitted by the filter. The central layer of the filter having thickness $\frac{\lambda}{2}$ is provided with means for varying its refractive index electrically to enable light passing through the filter to be suitably modulated.

One way of modifying the refractive index of the layer comprises providing on each side of the layer an electrically conductive film. These films may be made thin enough so that they do not unduly limit the passage of light through the filter. A convenient way of constructing the filter of the invention is by laying down successive layers of the stack by a process such as vapour deposition. This technique can give good control of the thickness of each layer and is suitable for preparing manufacturing quantities of the light modulation device.

By way of example embodiments of the invention will be explained with reference to the drawing accompanying the provisional specification in which

Figure 1 shows a section through a light modulation device according to the invention, and

Figure 2 is a graph showing the intensity T of light transmission through the interference filter against wavelength λ of light transmitted.

The well-known Fabry Perot interferometer utilises the fringes produced in transmitted light after multiple-reflection in an air film between two plane plates thinly silvered

[*Price 4s. 6d.*]

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on their inner surfaces. The light is usually from a broad source of monochromatic light. In a convenient construction of interference filter using this principle the air and mirror surfaces may be replaced with alternate solid layers of high and low refractive index.

The embodiment shown in Figure 1 was constructed by vapour depositing successive layers of the filter upon a transparent substrate. In this example this support is provided by a glass substrate 1. Before commencing the construction of an interference filter however it is necessary to predetermine the peak wavelength λ_o of light which is to be transmitted by the filter. This value is needed for enabling the required thickness of the interference layers to be calculated.

Upon one side of the substrate 1 is deposited by a vapour deposition process a layer with high refractive index. This layer 2 is of zinc sulphide. Upon this layer is deposited a further layer 3 having low refractive index of lithium fluoride. Further layers 4 of high refractive index, and 5 of low refractive index are then deposited in succession. All these layers are of thickness $\frac{\lambda_o}{4}$.

Upon the layer 5 of low refractive index a conductive film 6 is laid down. This film is of gold and is sufficiently thin so as to be transparent to the wavelength of light which is intended to be transmitted by the filter. This deposition is followed by the laying down of a layer 7 which is intended to be the central layer of the completed filter stack and has a thickness of $\frac{\lambda_o}{2}$. The central layer 7 is of barium titanate. The sequence of layers is then repeated upon the opposite side of this central layer. There are thus laid down successively a second conductive film 8, a layer 9 of low refractive index, a layer 10 of high refractive index, a layer 11 of low refractive index and a layer 12 of high refractive index. The four last-mentioned layers are all of thickness $\frac{\lambda_o}{4}$.

Connecting leads 13 are then joined to the electrically conductive films 6 and 8.

In operation, if a broad source of monochromatic light of suitable wavelength is placed at the substrate 1 side of the interference filter, the intensity of transmitted light may be measured by a suitable detector on the opposite side of the filter. The tuned wavelength of peak transmission of light through the filter is determined during manufacture by the thickness of the central layer 7 of the filter stack. This is of optical thickness $\frac{\lambda_o}{2}$ and all the other effective layers are of thickness $\frac{\lambda_o}{4}$. The tuning of the filter is effected so that a peak transmission of perhaps half of the incident light will be passed and a small alteration of the tuning caused by the refractive index change will thus be sufficient to cause a considerable variation in the intensity of the transmitted light. A typical graph of the intensity of light transmitted by the filter is shown in Figure 2. The intensity T is shown on a vertical scale and it will be seen that the transmitted light has one peak 14 at the wavelength λ_o which may be a wavelength of one micron and a sub-harmonic 15 is present at the wavelength $\lambda_1=2$ microns. When a suitable electrical potential is applied across the connecting leads 13 the refractive index of the layer having thickness $\frac{\lambda_o}{2}$ will be modified so that the intensity of light transmitted at these wavelengths will fall to the values shown by the dotted lines in Figure 2.

It can be shown that if the wavelength of peak transmission is for example 7,500 Ångstrom Units and the bandwidth is 15 Ångstrom Units then a change of refractive index n of one part in 1,000 is sufficient to reduce the transmission to 50% of that at peak. A change of refractive index n of one part in 100 would reduce the transmission to 1% of the peak value.

The foregoing description of an embodiment of the invention has been given by way of example only and a number of modifications may be made without departing from the scope of the invention. For instance instead of using a substrate of glass it may be made of any other suitable material which will be transparent to radiation passing through the filter.

It would be possible however for the substrate to be made of opaque material if provision was made for light passing through the filter to be reflected at the substrate surface. The materials used for construction of the interference layers may also be different from those specifically described in the example. The number of layers on either side of the central layer may also be varied from the number shown in the drawing.

The light modulator of the invention has been found to provide a compact way of utilising the electric field dependence of refractive index to give effective light modulation. The invention has been proposed for use in the field of electronically controlled absorption devices and in optoelectronic equipment.

WHAT WE CLAIM IS:—

1. A light modulation device comprising a stack of thin layers of transparent material

the layers having alternating high and low refractive indices and including one layer the refractive index of which may be varied by application of an electrical potential to the device.

2. A device as claimed in claim 1 in which the layer of variable refractive index is located at a central position in the stack.

3. A device as claimed in claim 1 in which the layer of variable refractive index includes an electrically conductive film on either side of said layer.

4. A device as claimed in claim 1 in which the layer of variable refractive index is of greater thickness than that of the other layers in the stack.

5. A device as claimed in claim 1 in which the layer of variable refractive index is of barium titanate.

6. A device as claimed in claim 1 in which the layers of high refractive index are of zinc sulphide.

7. A device as claimed in claim 1 in which the layers of low refractive index are of lithium fluoride.

8. A device as claimed in claim 1 in which the layers are laid down by a vapour deposition technique.

9. A device as claimed in claim 1 substantially as hereinbefore described with reference to the drawing accompanying the provisional specification.

10. A method of making a device as claimed in claim 1 substantially as hereinbefore described with reference to the drawing accompanying the provisional specification.

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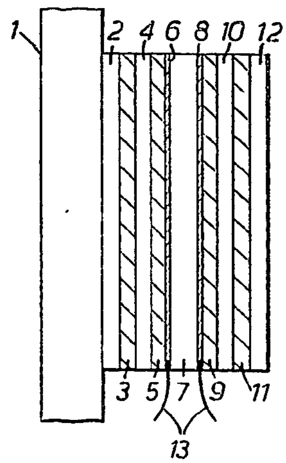


FIG. 1.

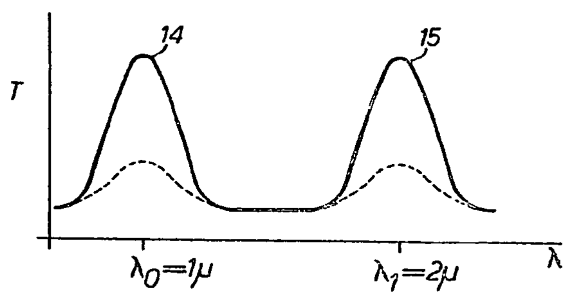
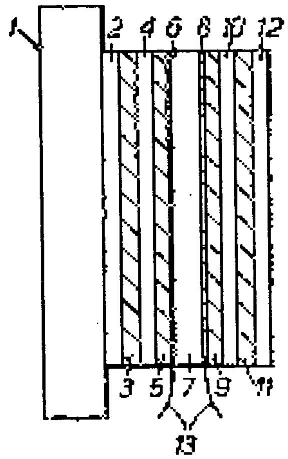


FIG. 2.



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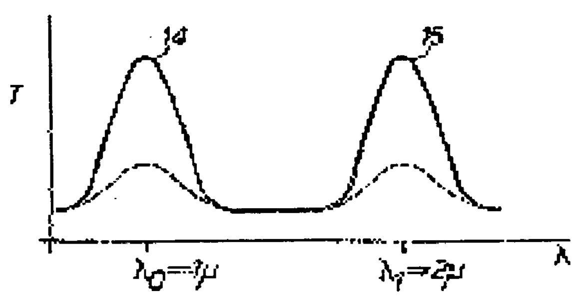

FIG. 2.